Aura MLS observations of the polar middle atmosphere: Dynamics and transport of CO and H_2O

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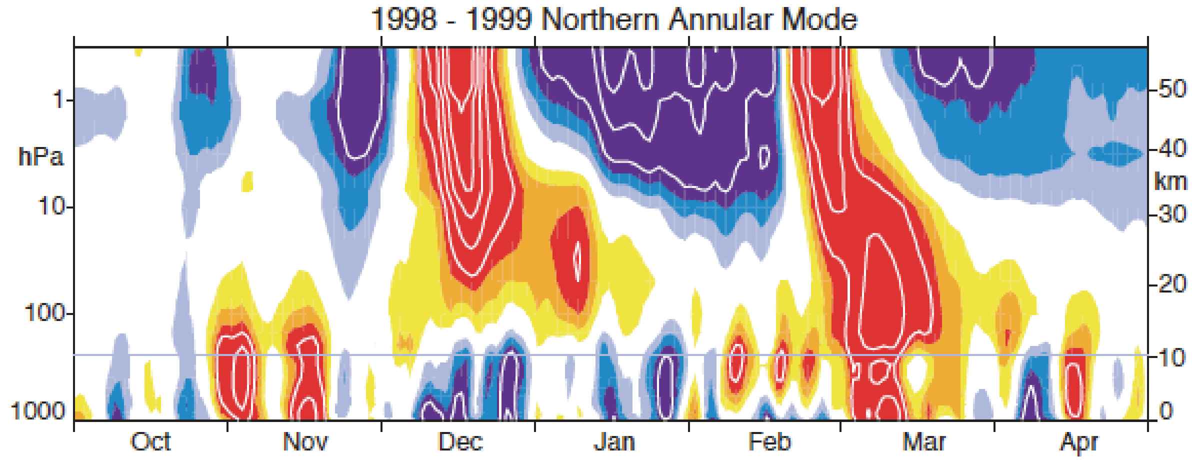
Outline

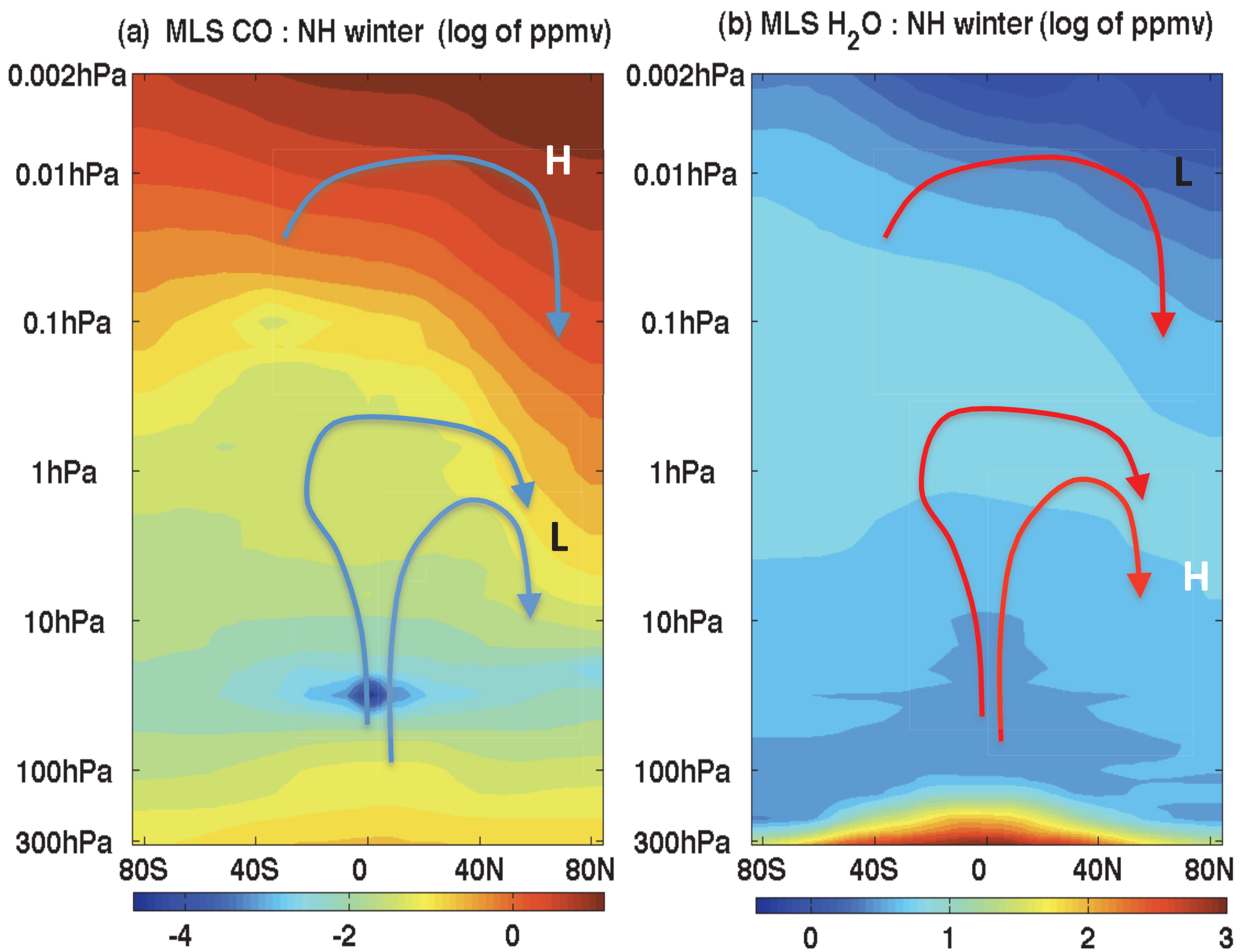
- EOF analysis and annular modes
- NAM and SAM from MLS GPH, CO, and H_2O
- Vertical descent of NAM and SAM
- Descent in the middle atmosphere

Baldwin and Dunkerton (2001)

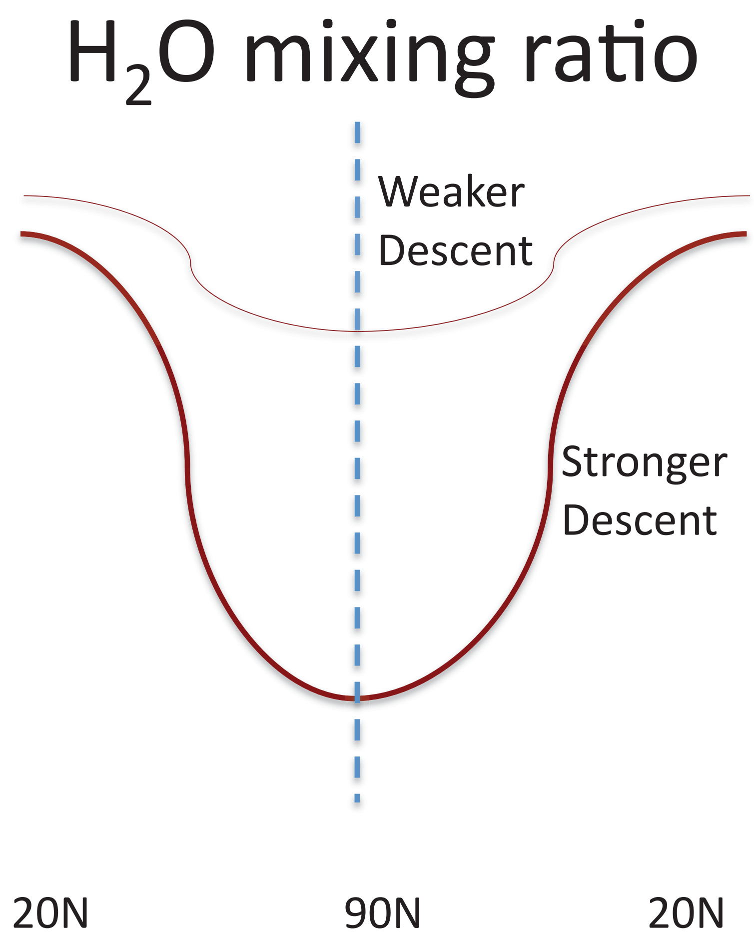


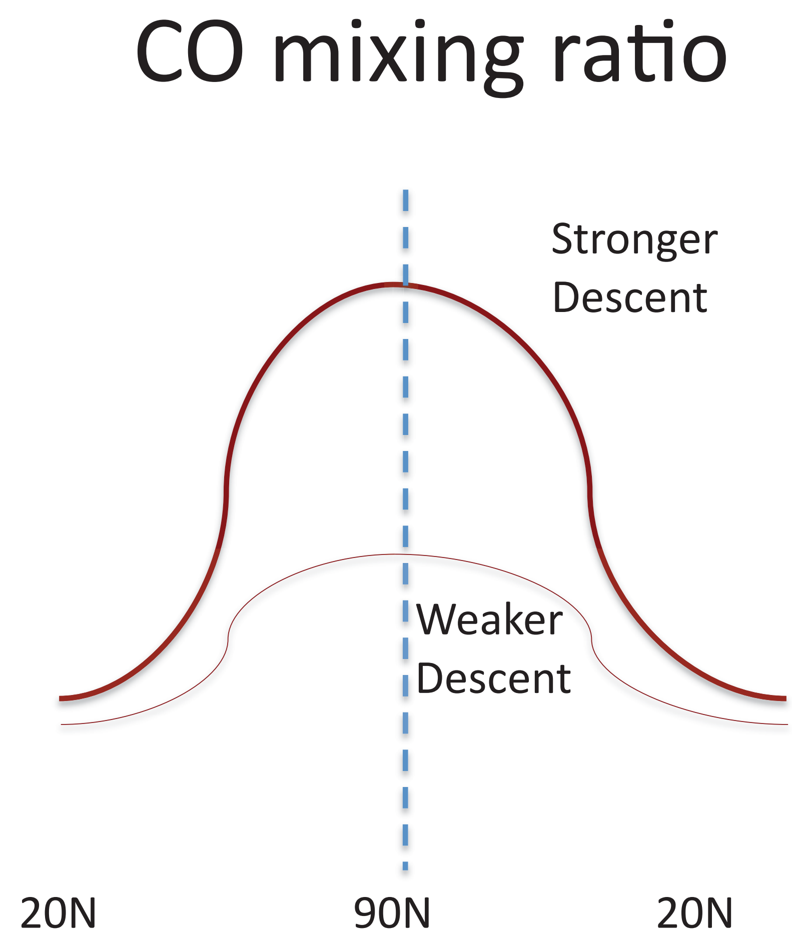
- Perturbations at 50 km descend to the lowermost stratosphere;
- Tropospheric weather patterns follow;
- Surface pressure perturbation patterns are called the Arctic Oscillation (AO) pattern;
- Stratospheric events show impacts on location of storm tracks.
- MLS observations – up to 90km. EOF analysis from Nov. – March.

Aura MLS CO and H_2O for DJF

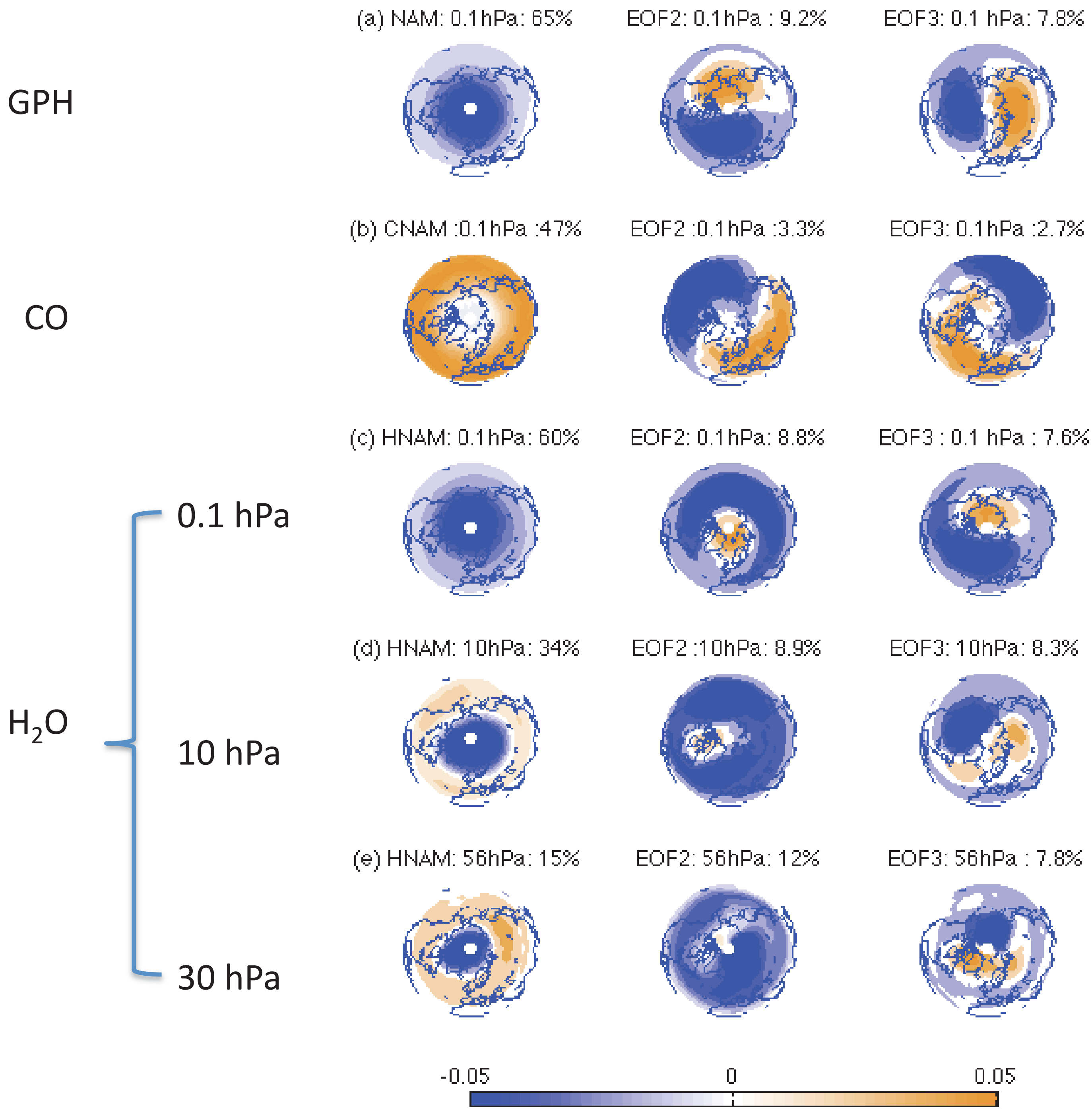


- Vertical and horizontal gradients of zonal mean CO and H2O structure.
- How does the polar descent shape up the tracer distribution?
- What is going to change during SSW? -> with strong perturbations.





If the tracer distribution has a meridional gradient that is not constant with height and time, and has a pronounced maximum somewhere, sometime, it may contain downward transport information.



GPH
CO
H_2O
0.1 hPa
10 hPa
30 hPa
(a) NAM: 0.1hPa: 65%
EOF2: 0.1hPa : 9.2%
EOF3: 0.1 hPa: 7.8%
(b) CNAM :0.1hPa :47%
EOF2 :0.1hPa :3.3%
EOF3: 0.1hPa :2.7%
(c) HNAM: 0.1hPa: 60%
EOF2: 0.1hPa: 8.8%
EOF3 : 0.1 hPa : 7.6%
(d) HNAM: 10hPa: 34%
EOF2 :10hPa: 8.9%
EOF3: 10hPa: 8.3%
(e) HNAM: 56hPa: 15%
EOF2: 56hPa: 12%
EOF3: 56hPa : 7.8%
-0.05
0
0.05

EOF1
or
NAM/SAM

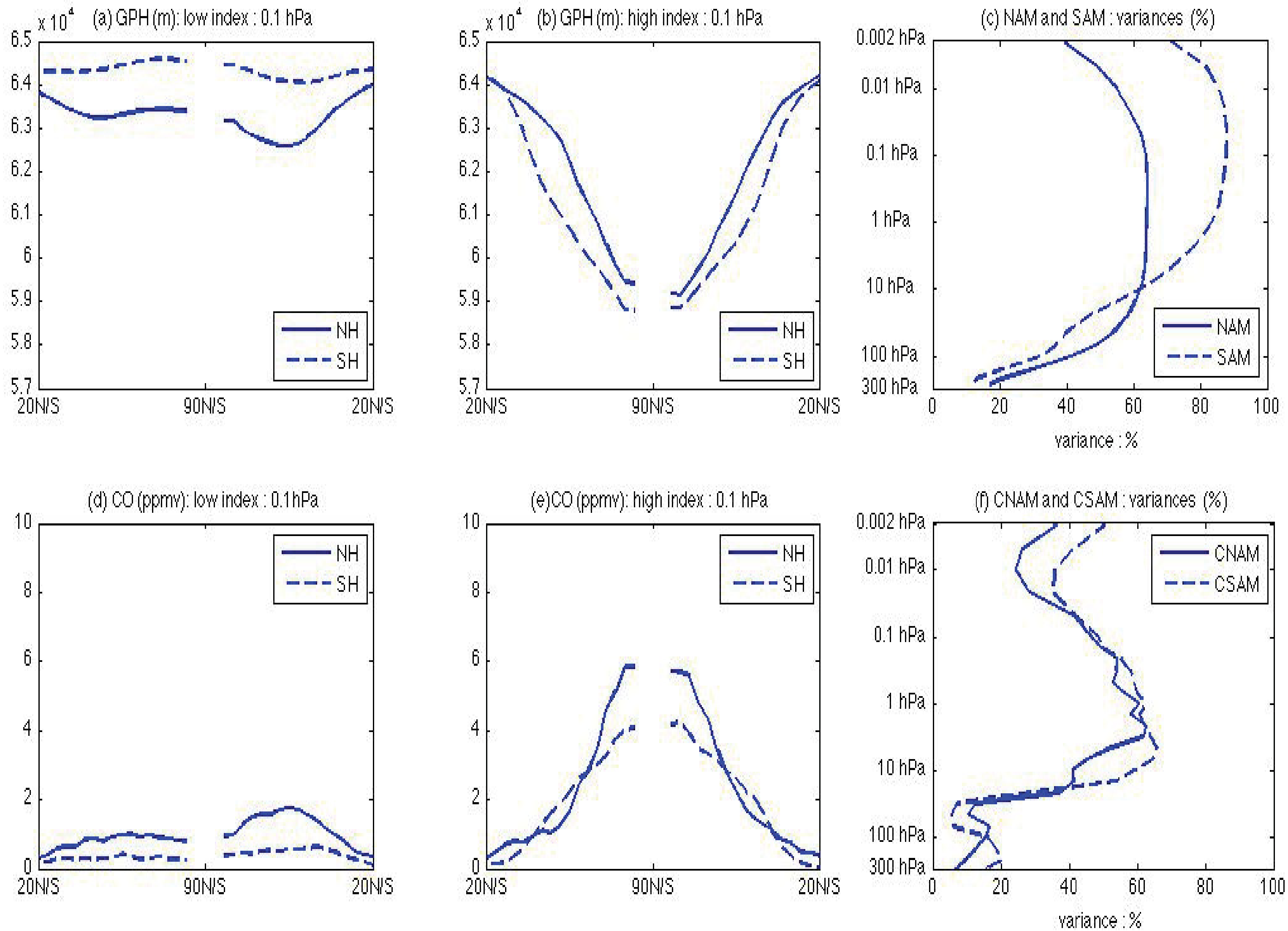
Low Index

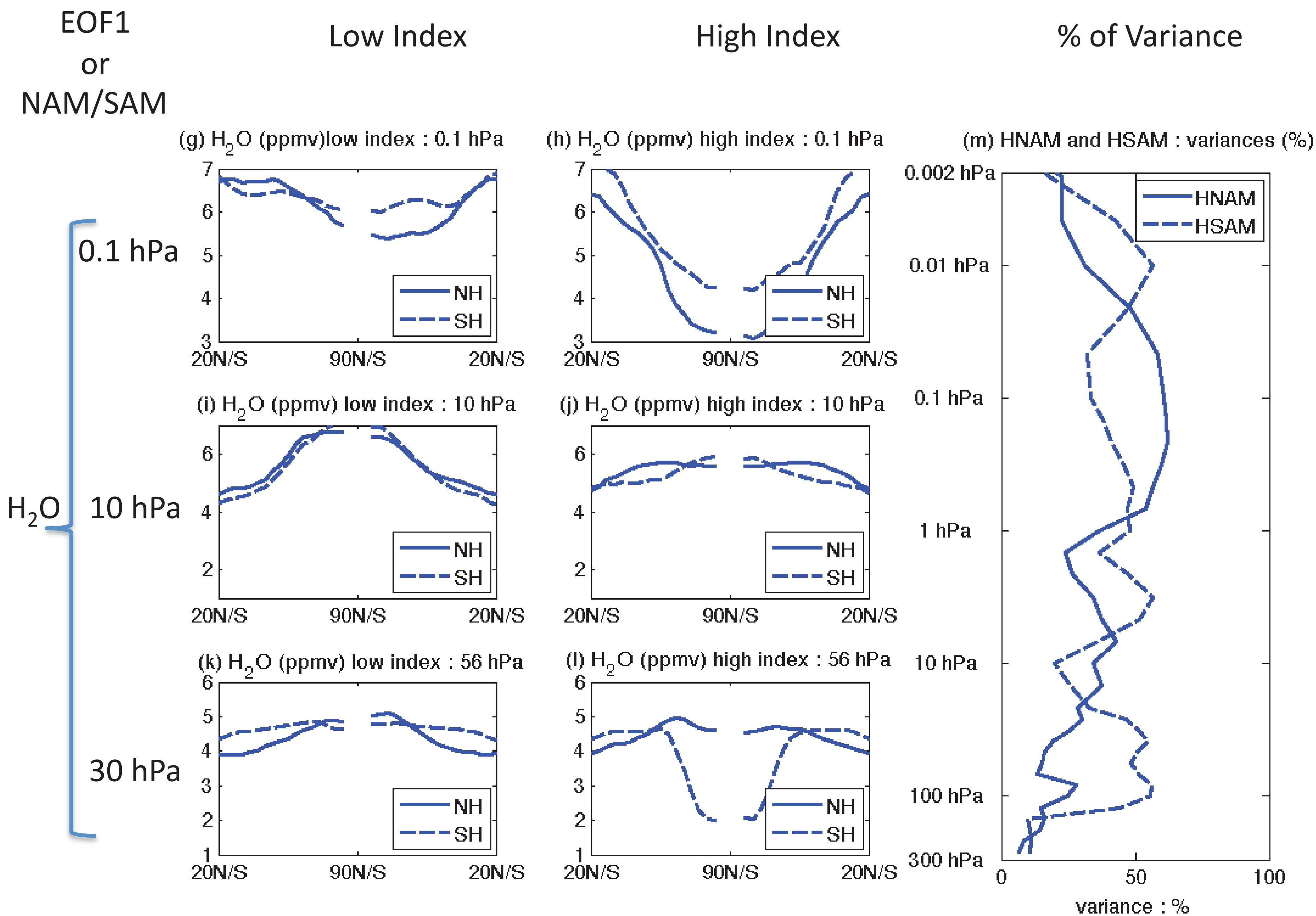
High Index

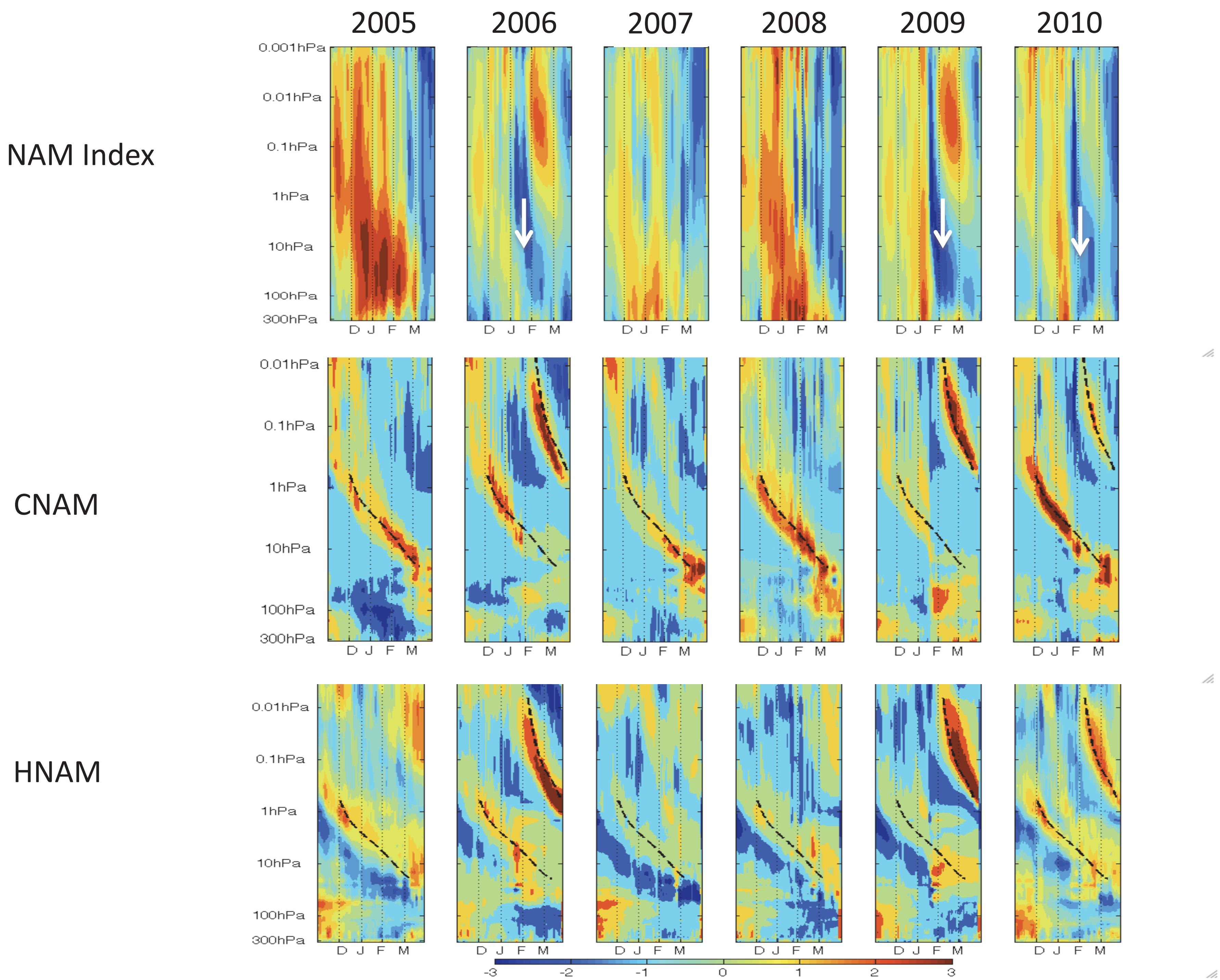
% of Variance

GPH

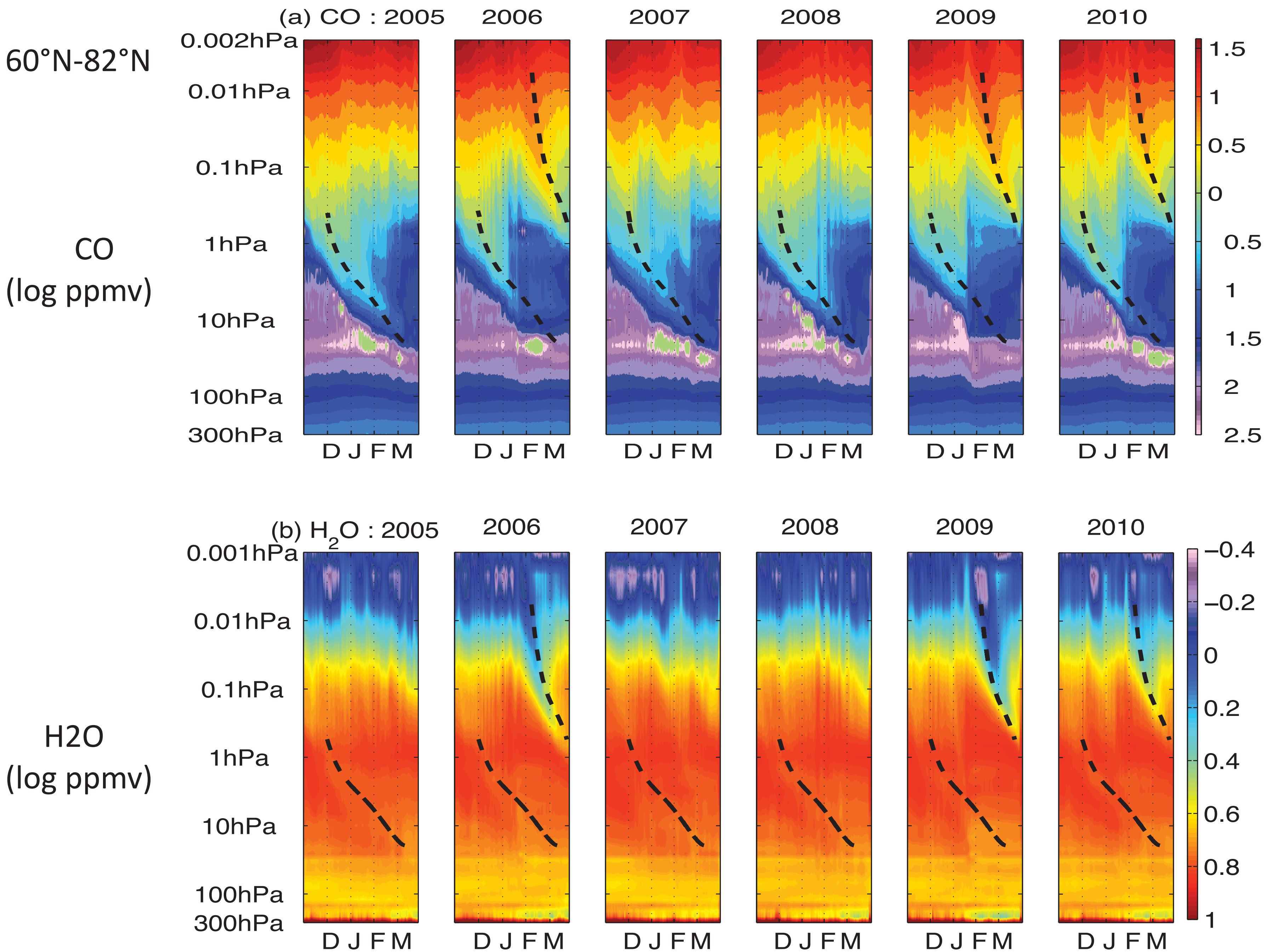
CO




EOF1
or
NAM/SAM
Low Index
High Index
% of Variance
H_2O
0.1 hPa
10 hPa
30 hPa
(g) H_2O (ppmv)low index : 0.1 hPa
(h) H_2O (ppmv) high index : 0.1 hPa
(i) H_2O (ppmv) low index : 10 hPa
(j) H_2O (ppmv) high index : 10 hPa
(k) H_2O (ppmv) low index : 56 hPa
(l) H_2O (ppmv) high index : 56 hPa
NH
SH
20N/S
90N/S
20N/S
(m) HNAM and HSAM : variances (%)
HNAM
HSAM
0.002 hPa
0.01 hPa
0.1 hPa
1 hPa
10 hPa
100 hPa
300 hPa
0
50
100
variance : %

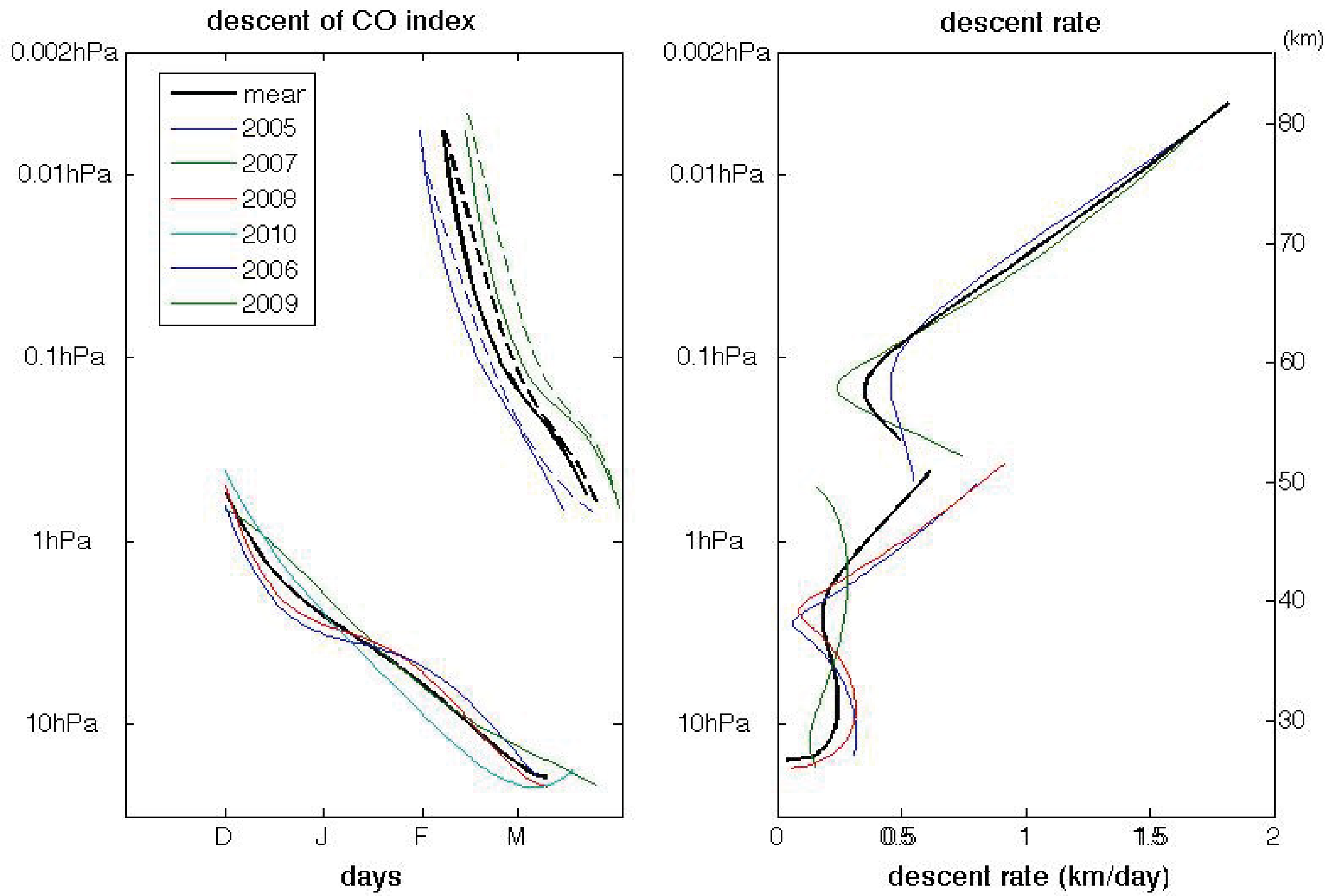


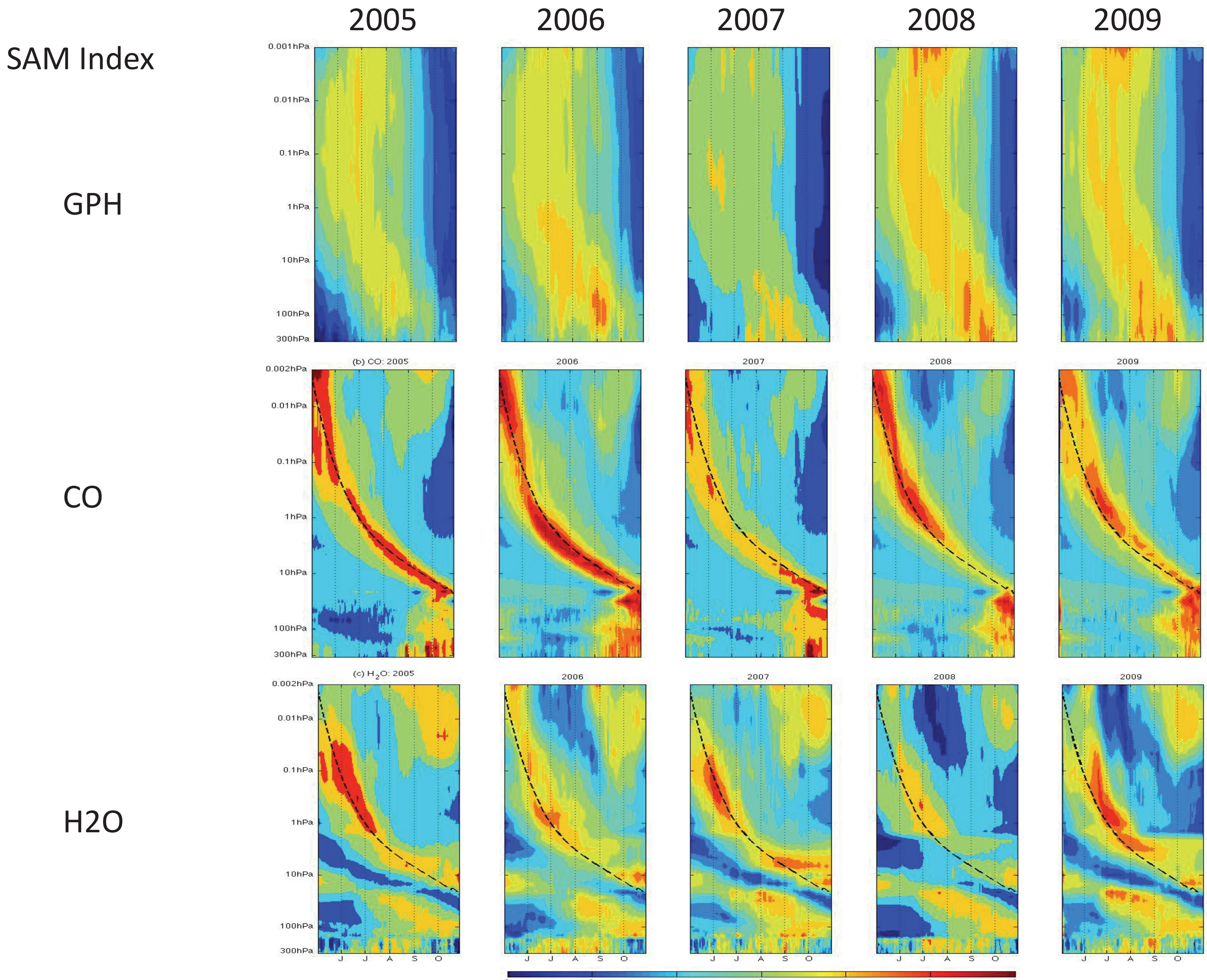
2005
2006
2007
2008
2009
2010
NAM Index
CNAM
HNAM
0.001hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
D J F M
-3
-2
-1
0
1
2
3


60°N-82°N
CO
(log ppmv)
H2O
(log ppmv)
(a) CO : 2005
2006
2007
2008
2009
2010
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
D J F M
1.5
1
0.5
0
0.5
1
1.5
2
2.5
(b) H2O : 2005
0.001hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1

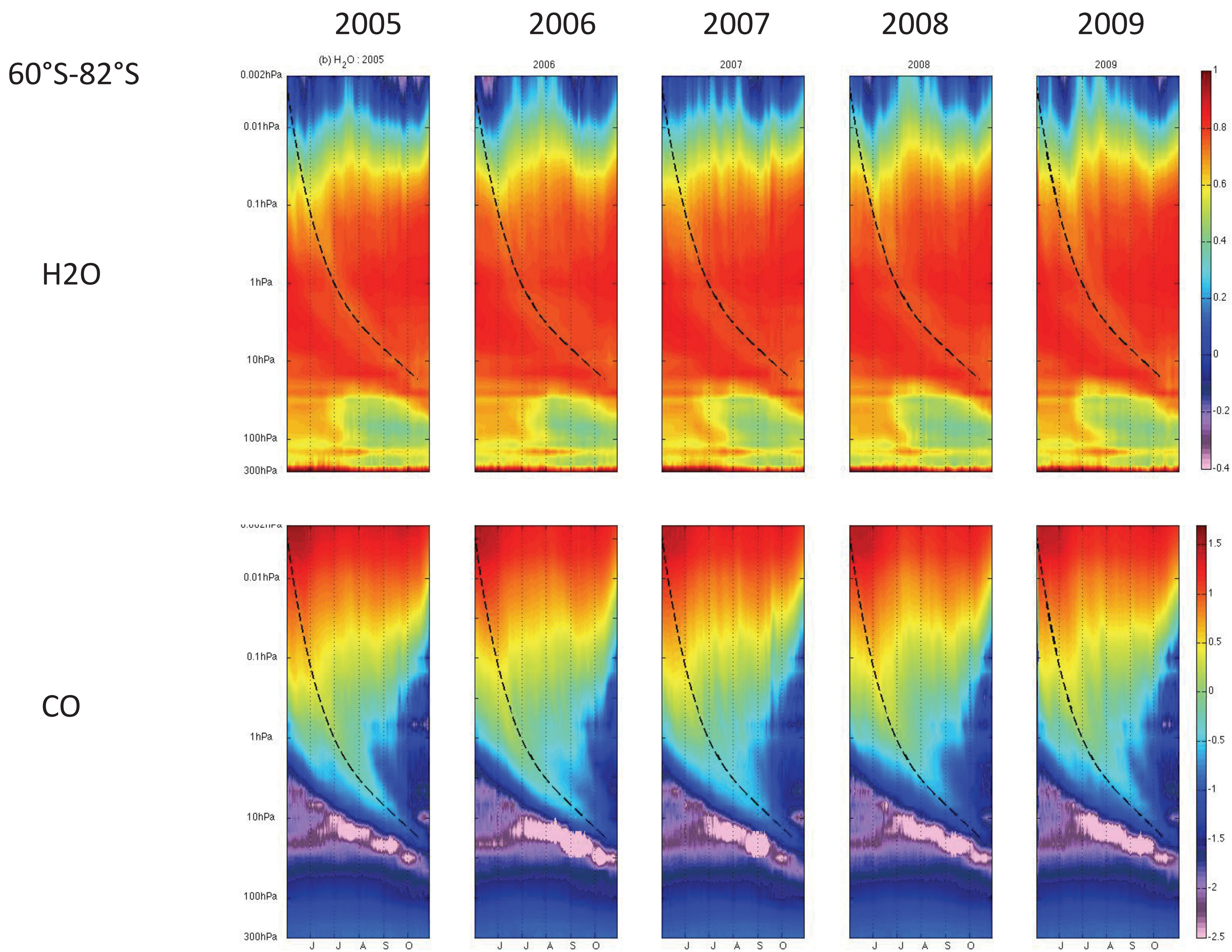
Z=0.5*g*t*t
=0.5*w*w/g
Dz/dw=w/g

At 60km, w=0.5 km/d
At 80km, w=1.8 km/d
Dw/dh = 1.3km/d/20km=0.07 /day

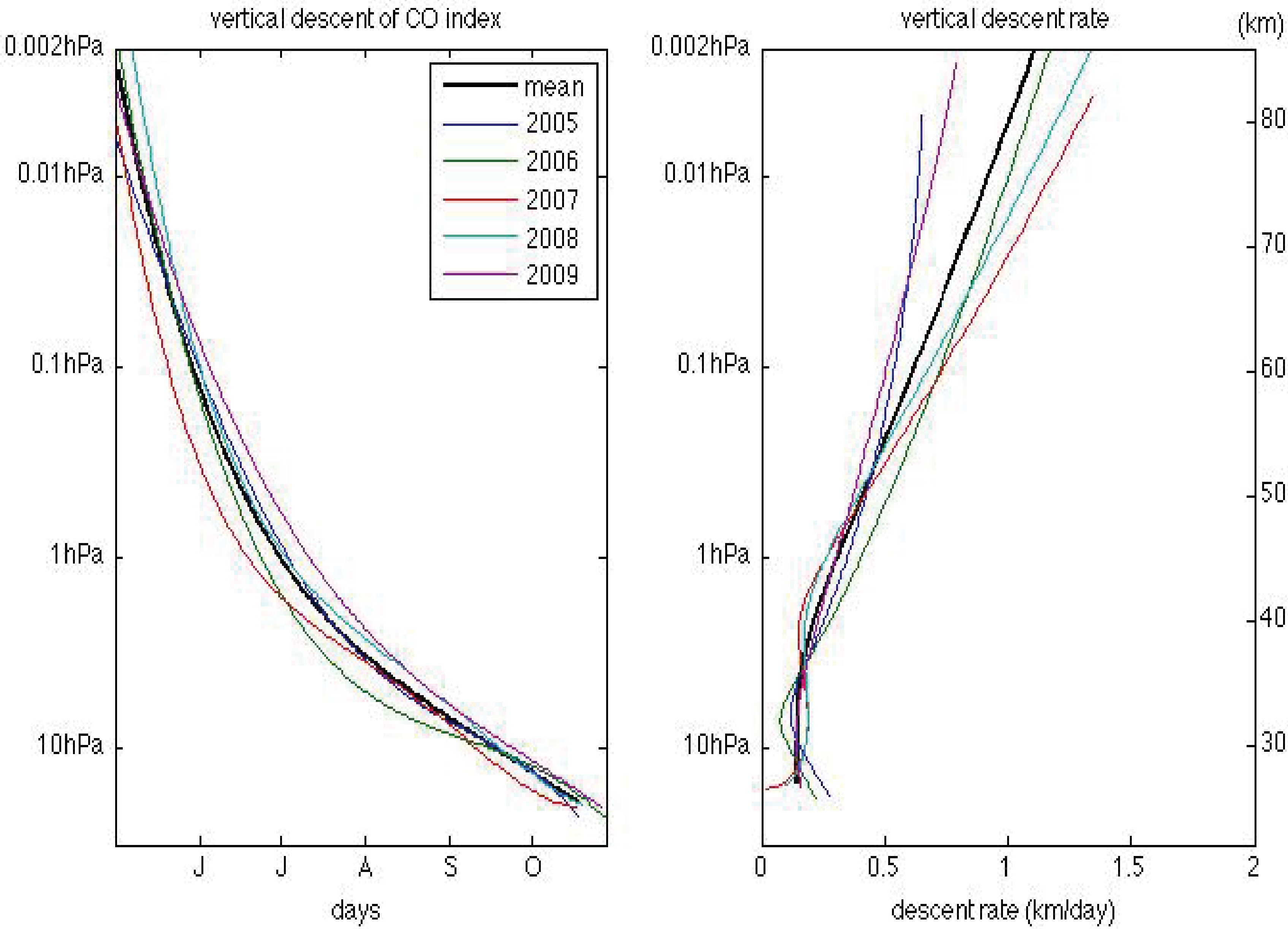




2005
2006
2007
2008
2009
SAM Index
GPH
CO
H2O
(b) CO: 2005
(c) H_2O: 2005
0.001hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
0.002hPa
J J A S O
-3 -2 -1 0 1 2 3



60°S-82°S
H2O
CO
2005
2006
2007
2008
2009
(b) H_2O : 2005
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
J
J
A
S
O



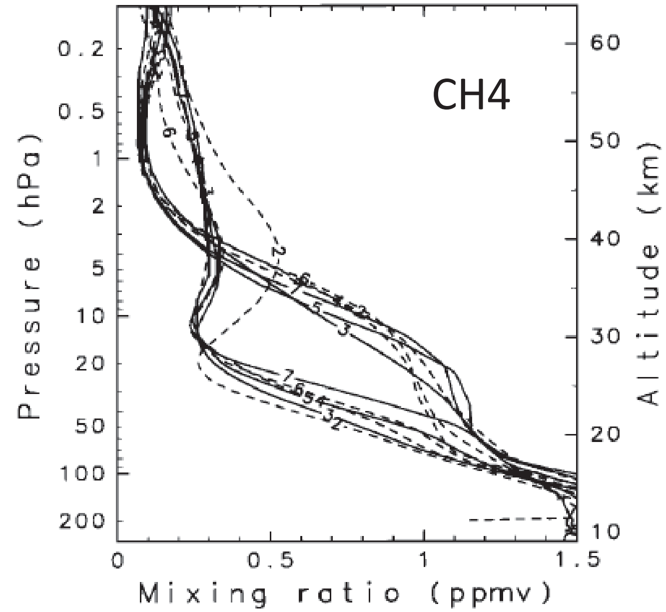
vertical descent of CO index
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
mean
2005
2006
2007
2008
2009
J
J
A
S
O
days
vertical descent rate
(km)
80
70
60
50
40
30
0
0.5
1
1.5
2
descent rate (km/day)

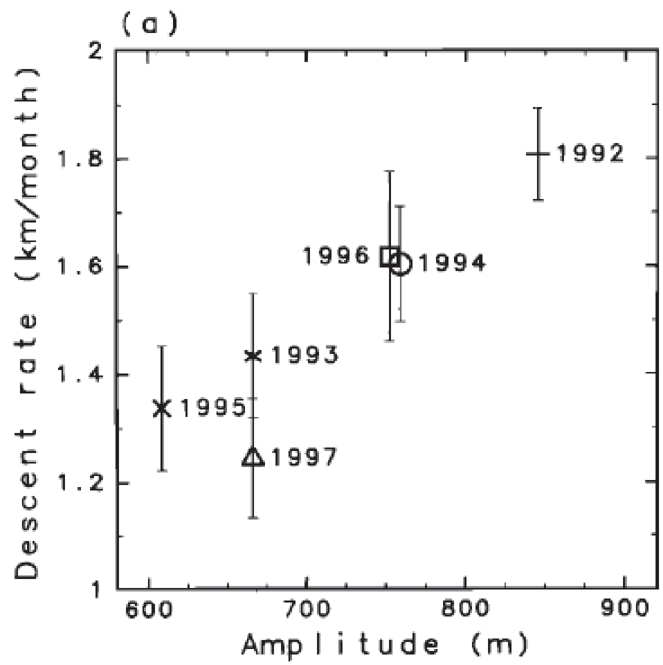
summary

- NAM/SAM (GPH) dominates the variance of polar winter in a broad range of altitude.
- MLS CO acts as a good tracer to polar atmospheric dynamics down to 30 km.
- More Rapid descent occurs in the upper mesosphere than in the stratosphere.
- Strong coupling is evident between middle and upper atmospheric CNAM, through interactions between planetary and gravity waves.

Kawamoto and Shiotani (2000)

- HALOE CH4 inside the Antarctic vortex
- 1.2-1.8 km/month at 0.6 ppmv with a biennial variation
- Adiabatic heating from the descent in the polar region

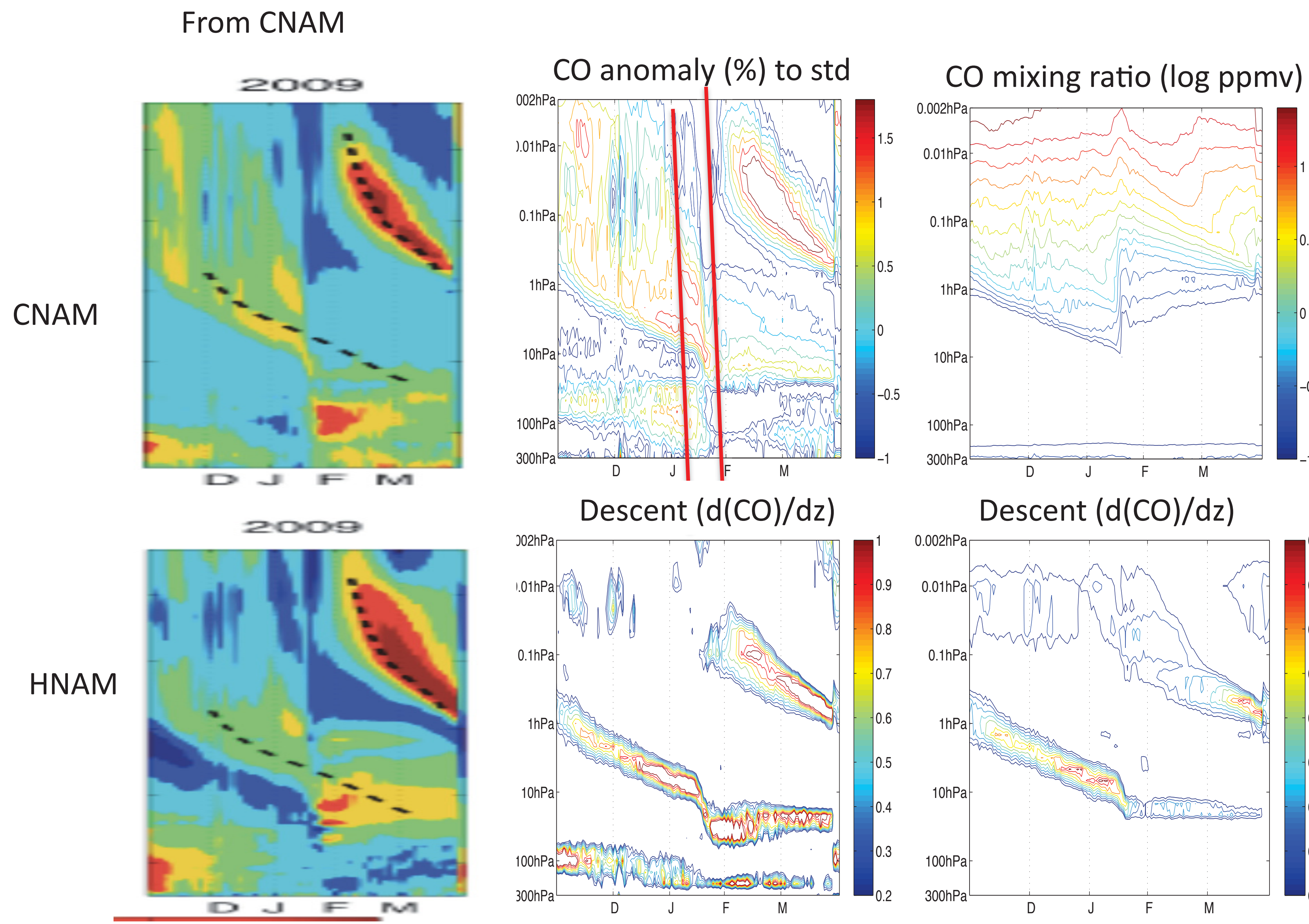




Wave 1 amplitude

Descent means?

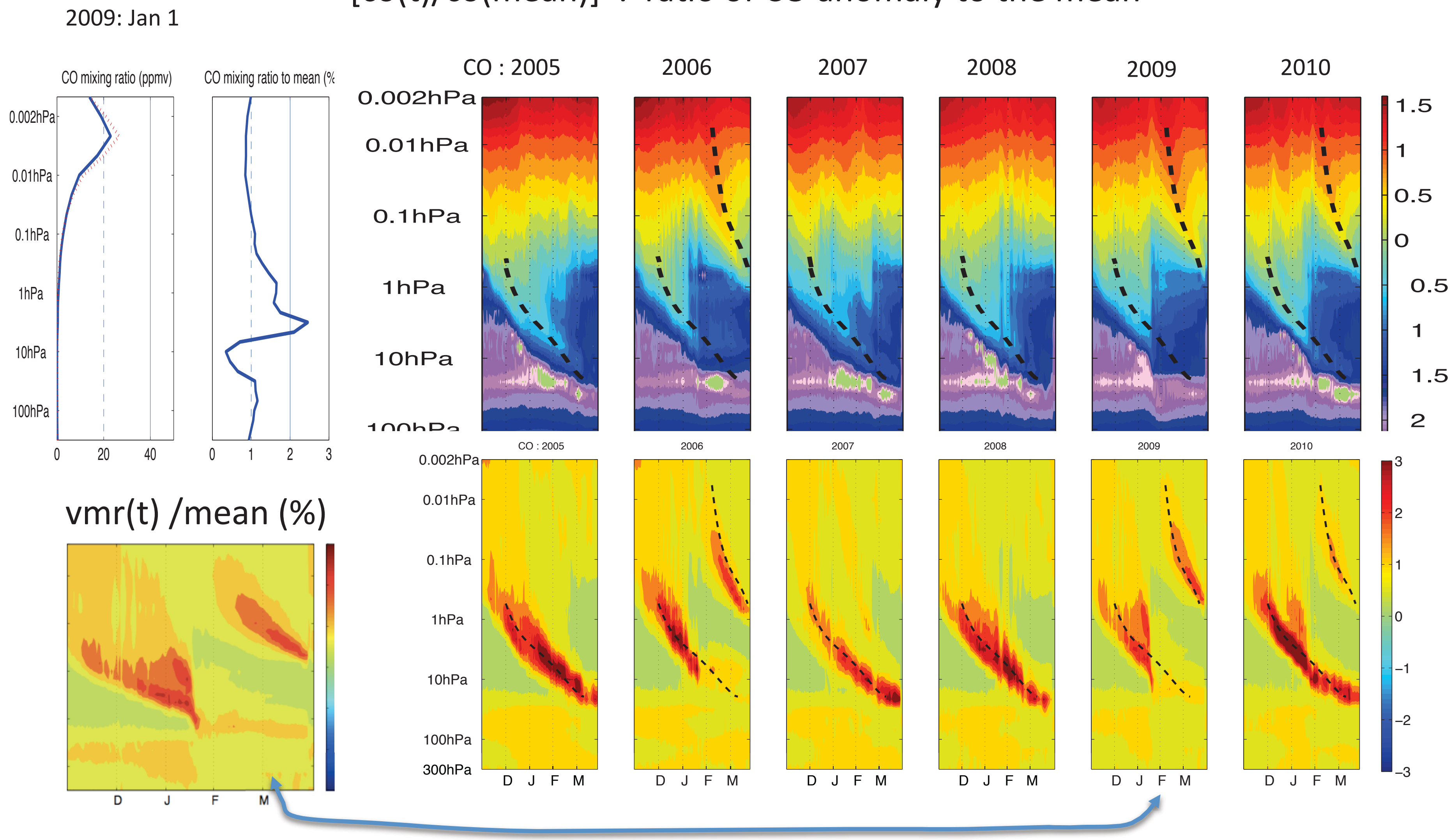
- Whole vortex descent?
- Constant mixing ratio gradient?
- Occurs at the center of air mass? Or at the bottom?



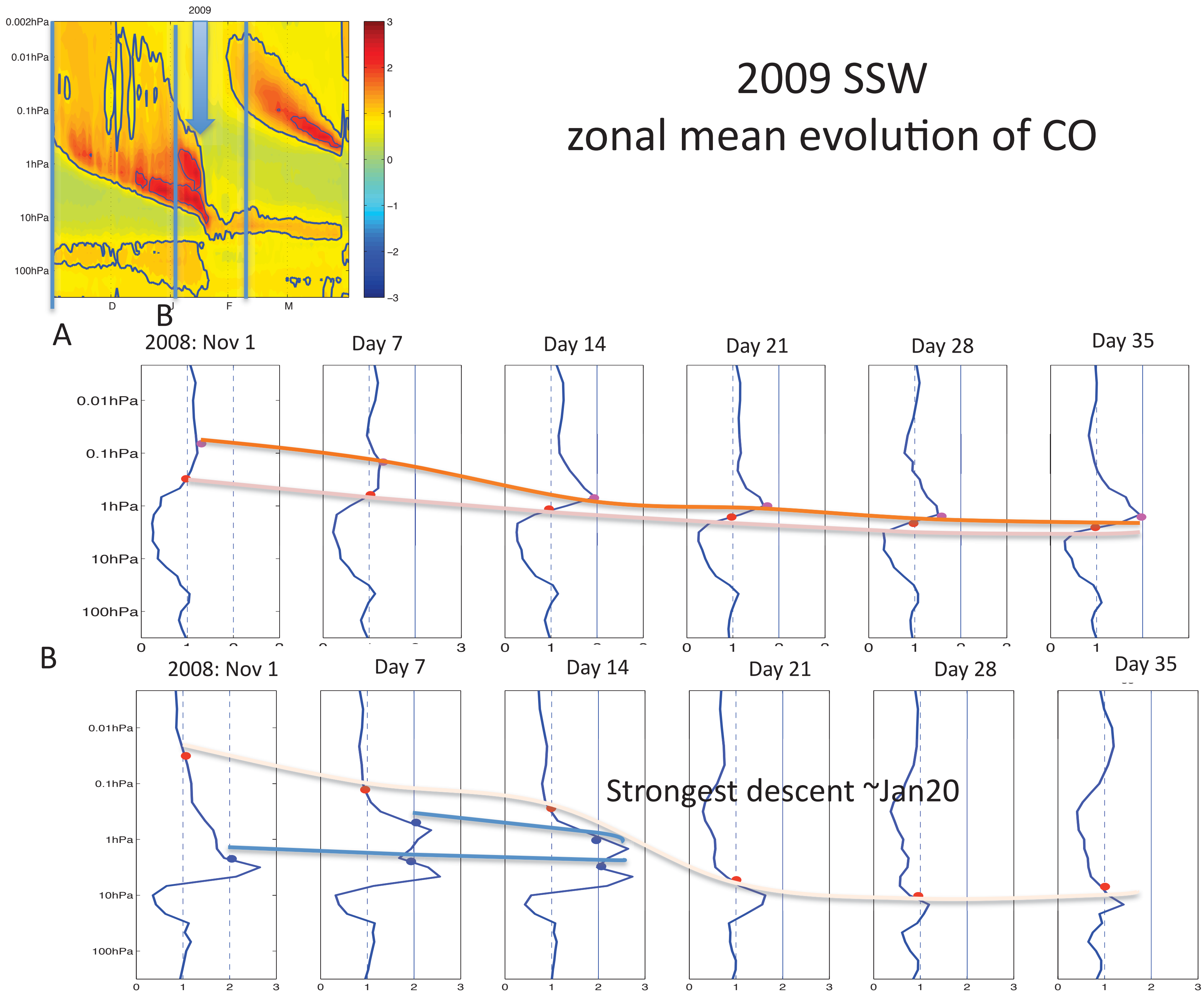
From CNAM
CNAM
HNAM
2009
2009
D J F M
CO anomaly (%) to std
CO mixing ratio (log ppmv)
Descent (d(CO)/dz)
Descent (d(CO)/dz)
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa

Time-height development of MLS CO zonal mean anomaly (70N – 82N)

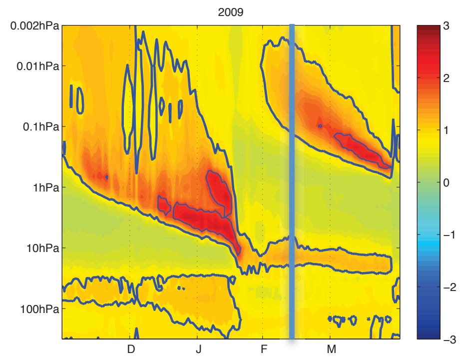
[co(t)/co(mean)] : ratio of CO anomaly to the mean

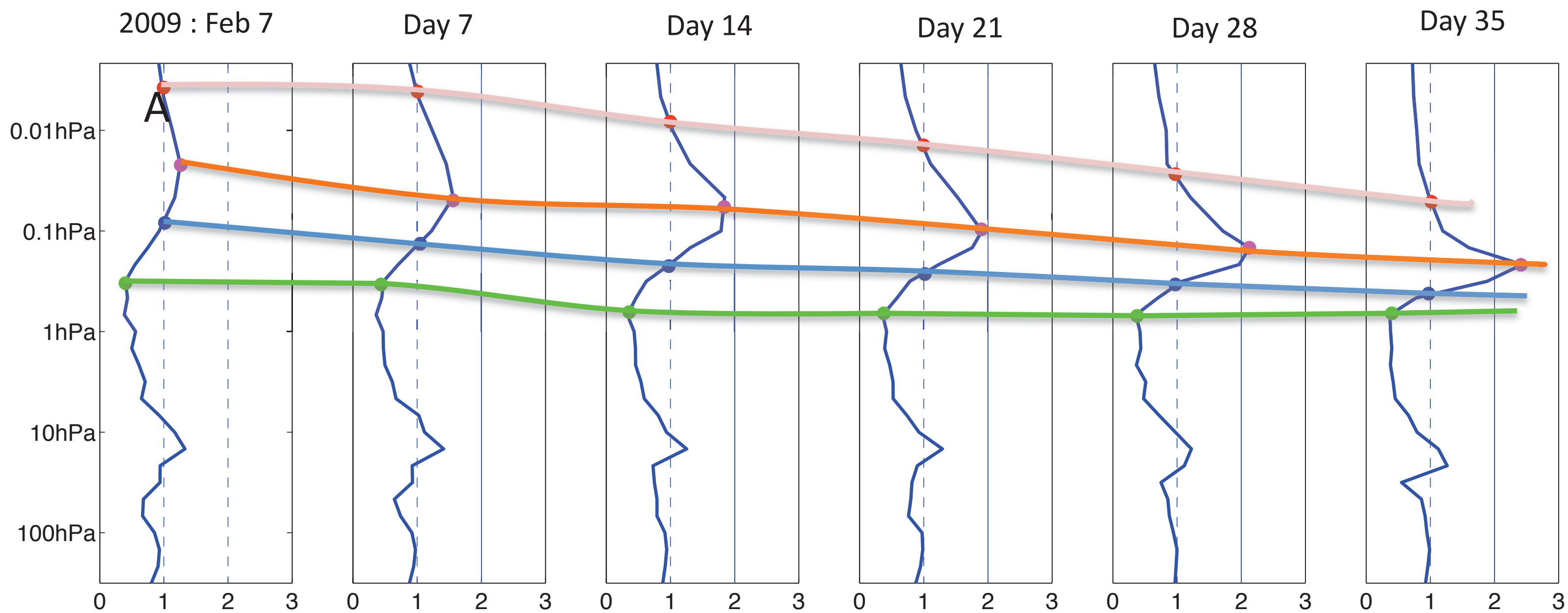


2009 SSW
zonal mean evolution of CO



Mesospheric descent in February





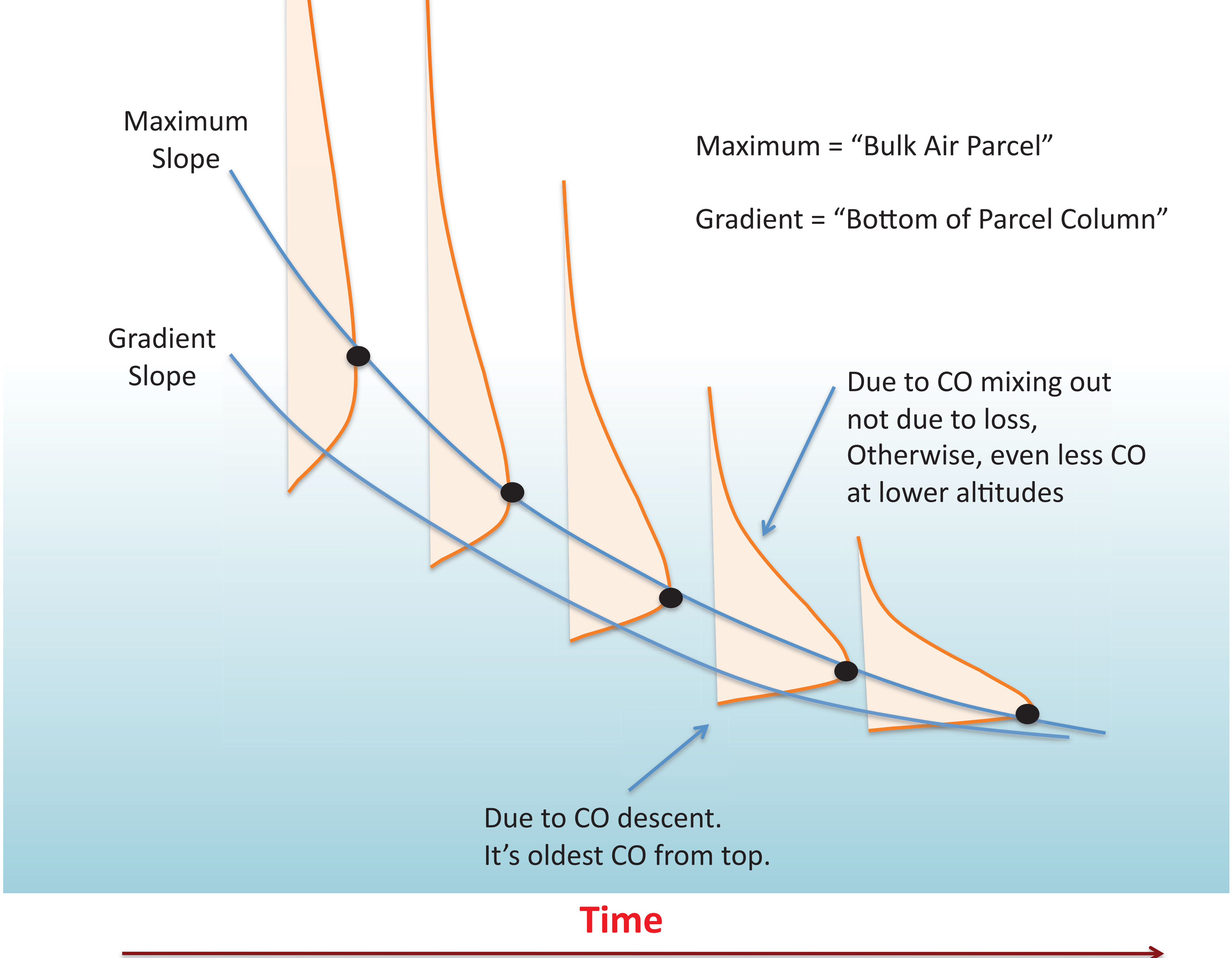
-- mixing ratio anomaly descent in higher altitude at 100% level

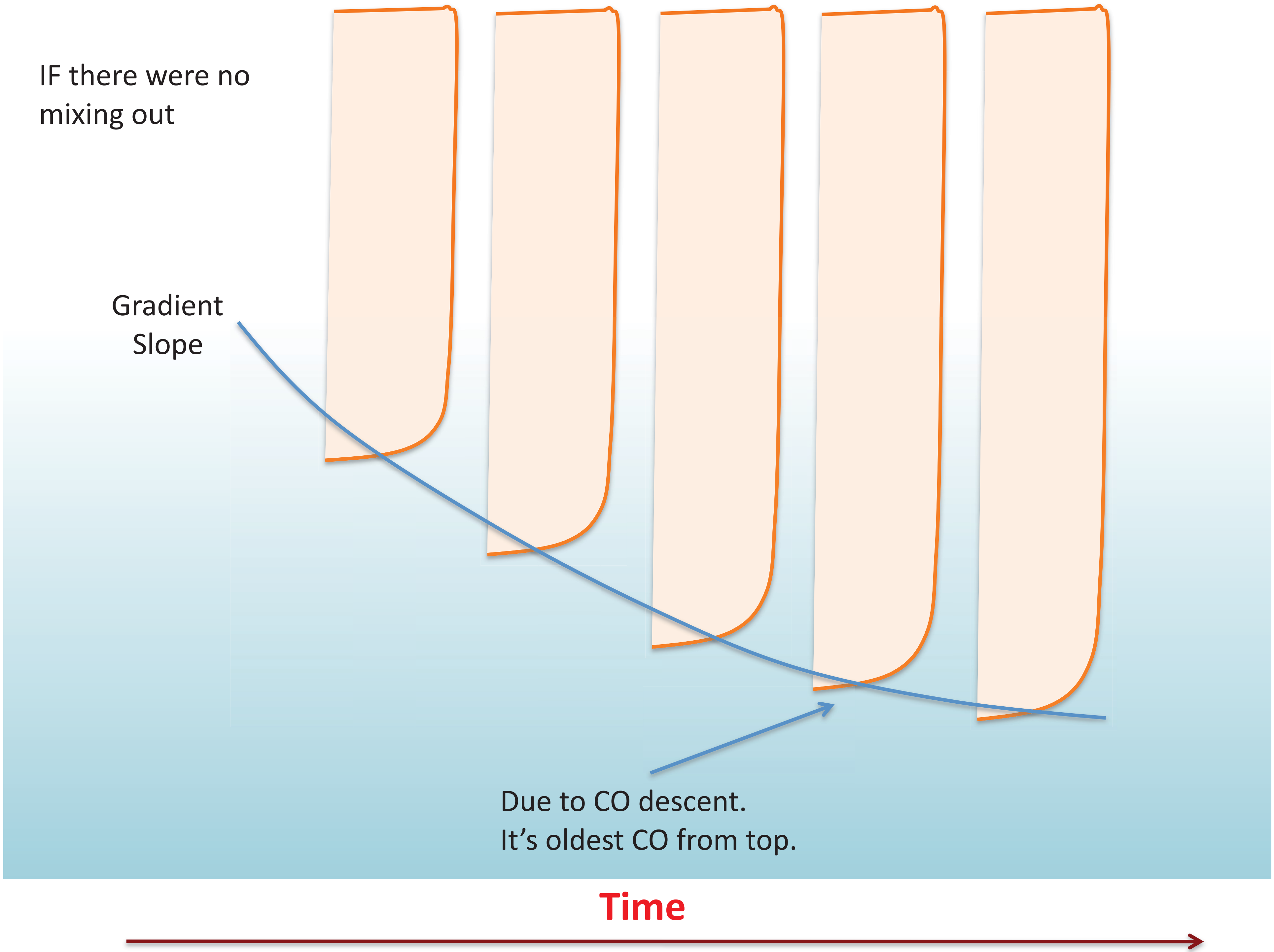
-- mixing ratio maximum anomaly descent

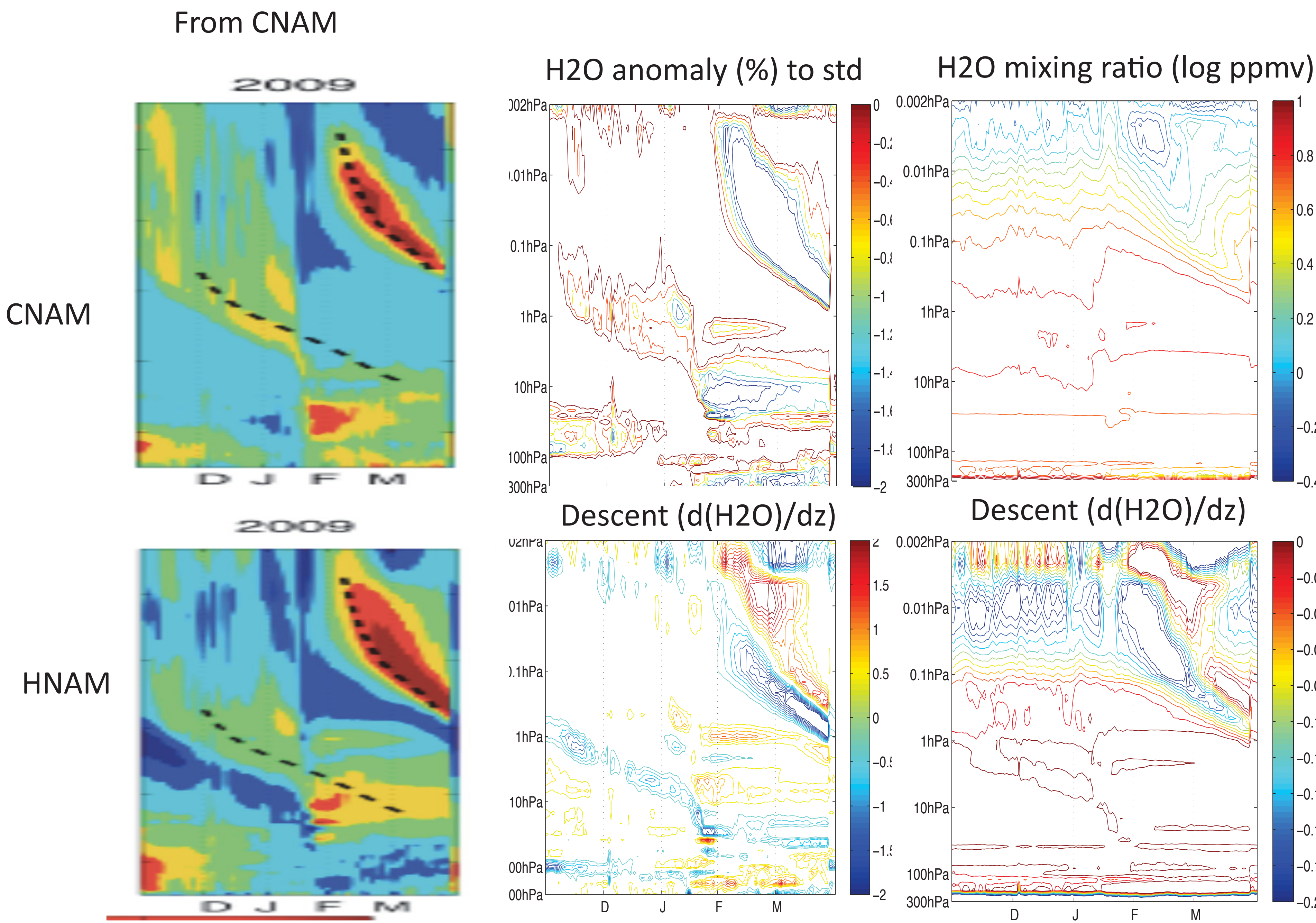
-- mixing ratio anomaly descent descent in lower altitude at 100% level

-- mixing ratio minimum anomaly descent

Time

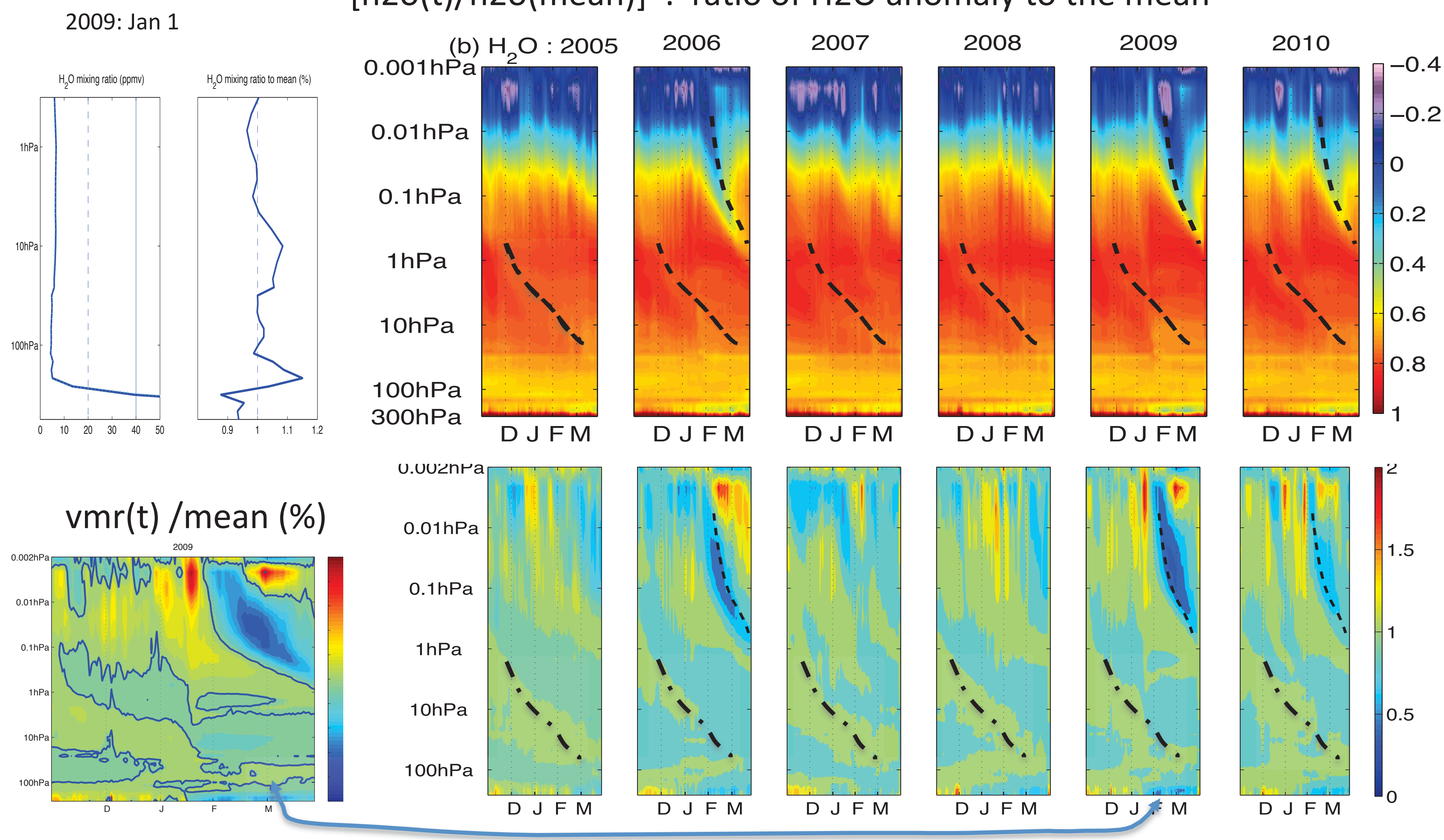

Maximum
Slope
Gradient
Slope
Maximum = “Bulk Air Parcel”
Gradient = “Bottom of Parcel Column”
Due to CO mixing out
not due to loss,
Otherwise, even less CO
at lower altitudes
Due to CO descent.
It’s oldest CO from top.
Time

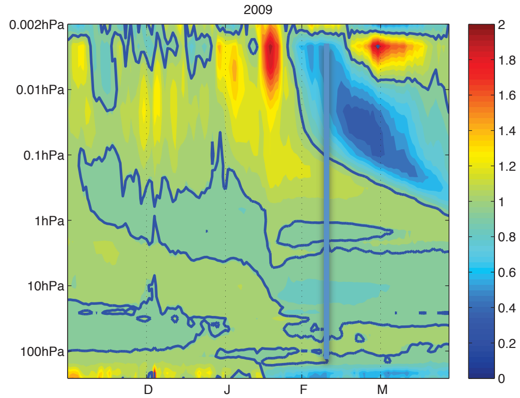

IF there were no
mixing out
Gradient
Slope
Due to CO descent.
It's oldest CO from top.
Time


From CNAM
2009
CNAM
2009
HNAM
D J F M
H2O anomaly (%) to std
H2O mixing ratio (log ppmv)
Descent (d(H2O)/dz)
Descent (d(H2O)/dz)
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
D
J
F
M

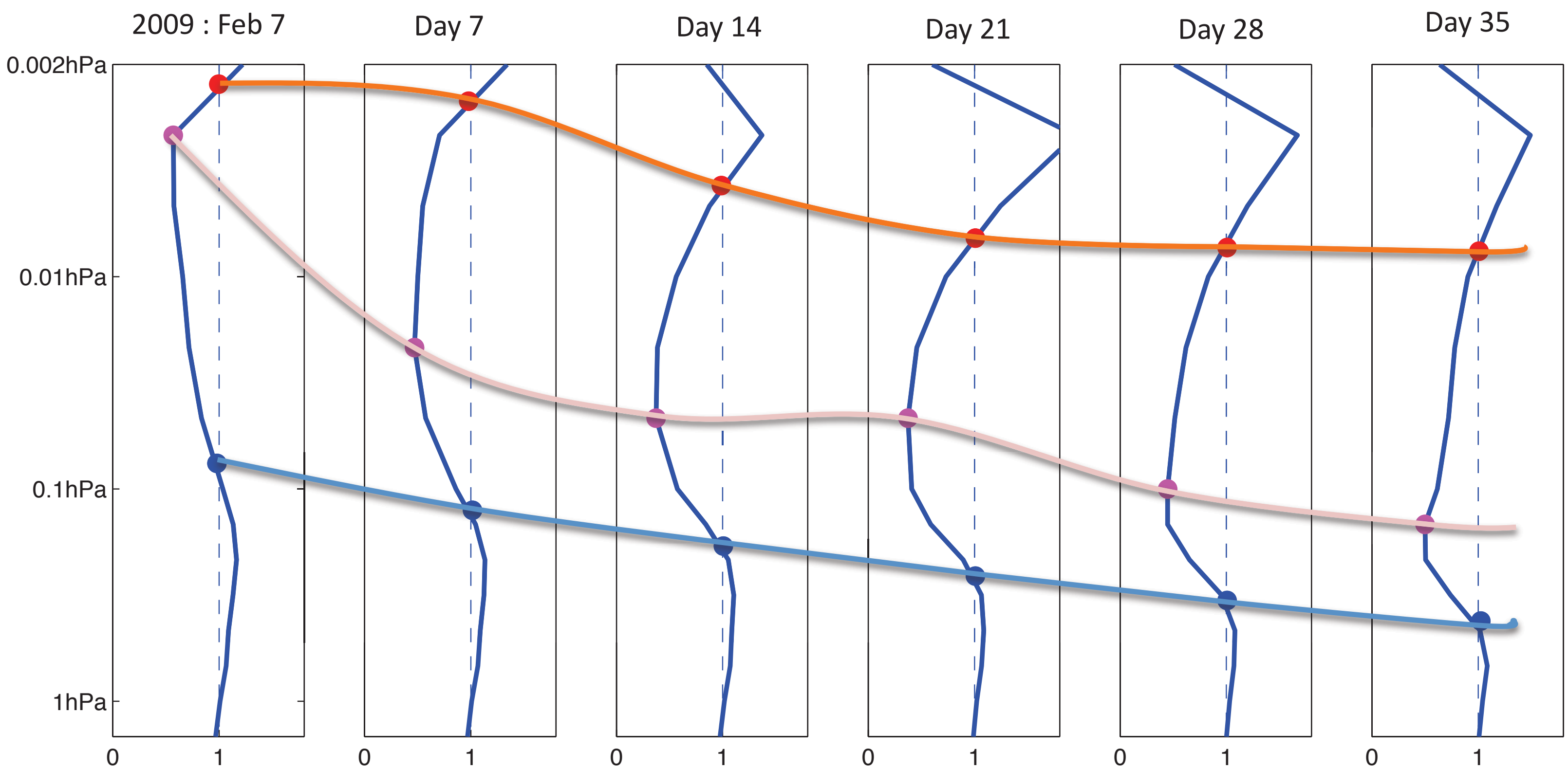
Time-height development of MLS H2O zonal mean anomaly (70N – 82N)

[h2o(t)/h2o(mean)] : ratio of H2O anomaly to the mean





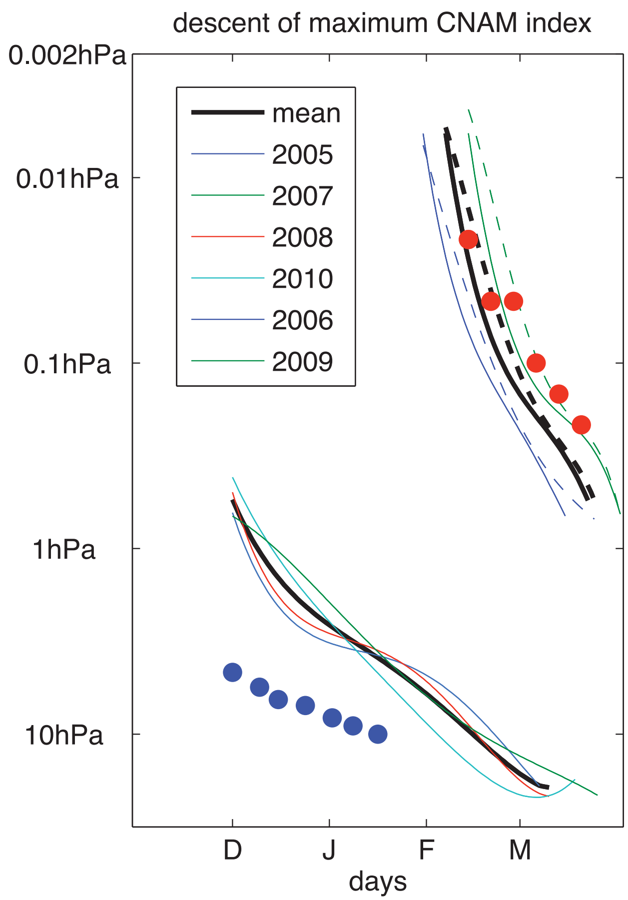
Mesospheric descent in February



-- mixing ratio minimum anomaly descent

Time

Comparison with CNAM



- Maximum anomaly descent in CO , in Feb, 2009, is similar to that of CNAM

- Descent of CO following 100% CO anomaly line in Descember 2009, is slower than that of CNAM

summary

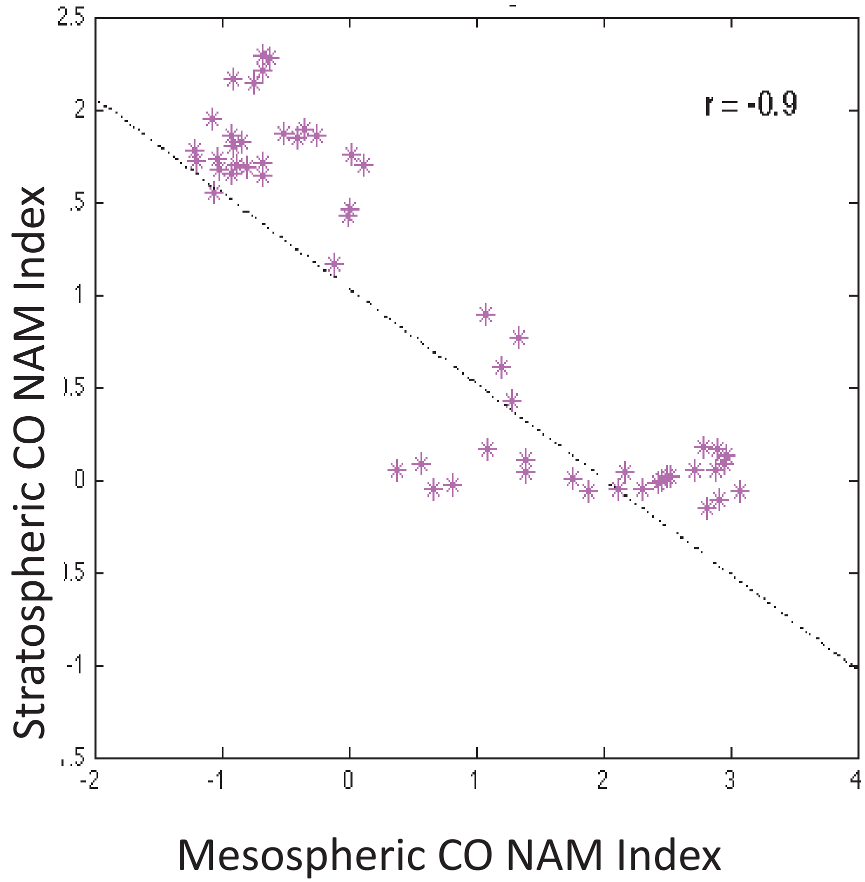
- Slope of the descent at the bottom of air mass is slower than that from the center of air mass.

Acknowledgement

- All MLS team members
- Co-authors and reviewers

Planetary and Gravity Wave Coupling

CO NAM Index during 1 – 10 March



- Mesosphere and stratosphere CNAM anti- correlated

- Planetary and Gravity wave coupling

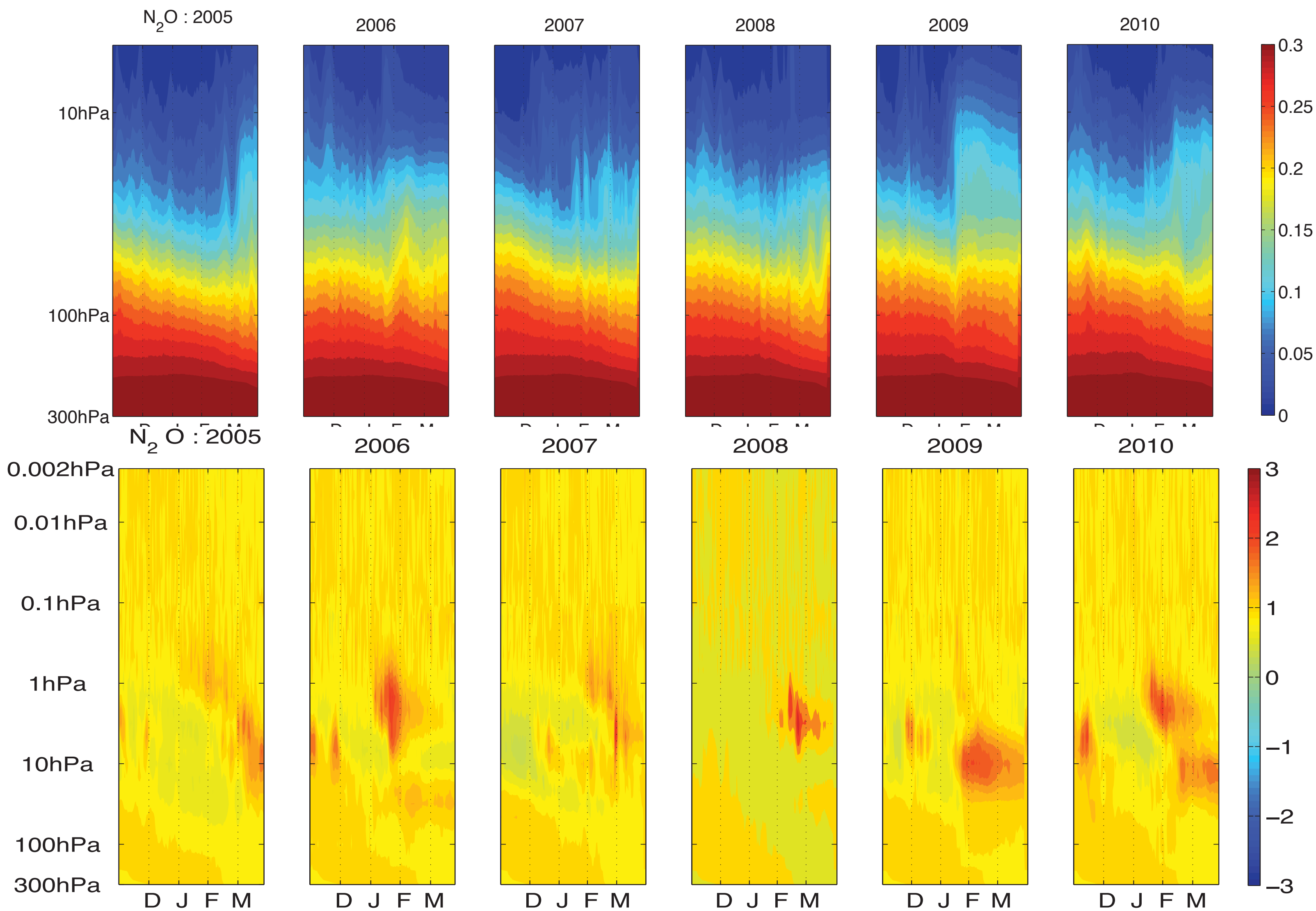
-weak vortices in the stratosphere (low index)

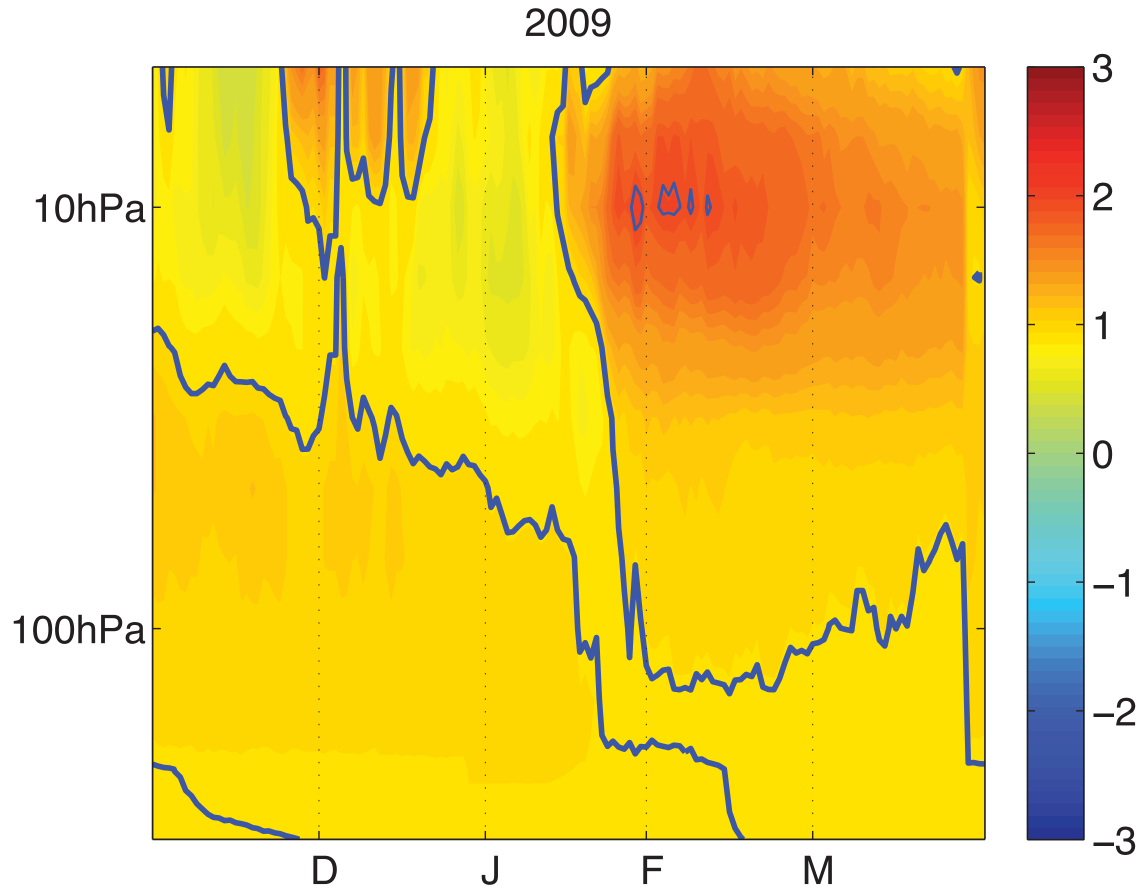
→ Prevents gravity wave propagating upward

→ forming strong vortex in the mesosphere

→ Siskind et al. [2010]

Zonal mean evolution of N_2O




2009
10hPa
100hPa
D
J
F
M
3
2
1
0
−1
−2
−3